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THE CAUSE OF METEOR FLARES*

by

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Meteor Flares

Sudden increases in brightness of meteors are called flares. They are very brief. The duration of flares is within the limits of from 0.001 to 0.1 seconds. The flares are displaced towards the end of their path with an increase in meteor velocity. The heights of the flares are extremely varied -- from 70 to 100 km. During flares, the brightness of meteors increases by 1 to 5 stellar magnitudes.

The views of meteor researchers on the physical nature of flares are very conflicting. For instance, in the opinion of Yakkiy, they occur as the result of fragmentation of the meteor body and the throwing of a mass from its surface. Cook, Eyring and Thomas saw the cause of flares in the ejection of the superheated surface layer of the meteor substance. Chervinsky explained flares by the change in orientation of the meteor body in space. In the opinion of

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Millman and Astapovich, meteors contain easily-fused impregnations, which, vaporizing, give off a sudden increase in meteor brightness. According to the views listed, the caues of flares lie not in the atmosphere but in the meteor bodies themselves.

We turn to the physical theory of meteors and look to see how it explains flares. The equation for vaporization of a meteor body has the appearance:

$$\frac{dm}{dt} = -\frac{a}{2Q} S v^3 \rho, \tag{1}$$

where m -- the mass of the meteor body, S -- area of any section of the meteor, v -- velocity of the meteor, Q -- energy necessary for heating and vaporizing 1 g of the meteor substance, ρ -- density of the atmosphere, and $\overline{a}$ -- coefficient of accomodation which characterizes the loss of kinetic energy of a molecule of air during a strike on the surface of the meteor.

The instantaneous force of light at a given point in the meteor's path gives the equation for brightness:

$$I = -\frac{\tau}{4\pi} \frac{dm}{dt} \frac{v^2}{2}, \tag{2}$$

where τ -- coefficient of luminance. In deriving equations (1) and (2), it has been accepted to consider:

1) The coefficient of luminance τ to be in a linear dependence on velocity, i.e., $\tau = \tau_0 v$ and ($\lg \tau_0 = -19.21$ (according to Epik)),

2) Atmospheric density changes with altitude according to the characteristic law $\rho = \rho_0 e^{-\frac{H}{H^*}}$, where H* -- height of a uniform atmosphere. With these propositions, the luminance equation does not contain values explaining meteor flares. The shapes of luminescence curves must be identical and without sudden increases in luminescence for all meteors. This deduction from the physical theory of meteor brightness is in conflict with facts of observation. It is apparent to us that we must turn to investigation of observed data relating to the physical condition of the atmosphere at altitudes of 70 to 100 km. We

must explain whether or not there is a cause in the atmosphere itself for a sudden increase in meteor luminescence.

According to meteor observations on the Harvard Observatory, the logarithm of atmospheric density at an average meteor inclination altitude of 110 km is equal to -9.131, and that for the average altitude of extinguishing is -6.421, which correspond to densities of $\rho_1 - 7.4 \cdot 10^{-10}$ and $\rho_2 = 3.8 \cdot 10^{-7}$ g/cm^3. The relationship between these values will be:

$$\frac{\rho_2}{\rho_1} = \frac{3.8 \cdot 10^{-7}}{7.4 \cdot 10^{-10}} = 500.$$

Such a large change in atmospheric density doubtless has an effect both on vaporization of the meteor substance and on illumination of meteors. Usually, in the first half of its course, the meteor's brightness will increase from zero to one stellar magnitude and more, and in the second half of its path, brightness rapidly decreases. By the end of its flight, one or more bright flares can often be observed.

At the present time, the structure of the atmosphere in the meteor zone is being intensively studied with visual, photographic, radio location and rocket observations. All these methods definitely show the very complex character of air flows at altitude of 60 to 110 km. Besides regular air mass movements in a horizontal direction with velocities up to 120 m/sec, intensive whirling movements with an average vertical velocity gradient up to 12 m/sec also exist. Width of the vertical streams amounts to 6 to 8 km, and that of the horizontal ones amounts to 3 to 20 km. All observation data point up to the fact that the atmosphere in the meteor zone is in a condition of turbulent motion. It is a gas medium with a changing density. During the movement of a meteor in such a disturbed atmosphere it is unavoidable that flares in its brightness must be observed..

Let us take an example. Let the meteor first move in an atmosphere with a density of $\rho_1 = 8.6 \cdot 10^{-10}$ g/cm^3 (H = 100 km), and then meet an air vortex in its path with a density of $\rho_2 = 8.6 \cdot 10^{-8}$ g/cm^3. We will evaluate the change in the meteor's luminescence under these movement conditions. For this, we set the derivative $\frac{dm}{dt}$ from vaporization equation (1) into brightness equation (2). For simplicity, we will consider the velocity of the meteor to be constant:

$$I = -\frac{\tau}{4\pi} \cdot \frac{dm}{dt} \cdot \frac{v^2}{2} = \frac{\tau \cdot \bar{a} \cdot S \cdot v^5 \cdot \rho}{16Q} = A\rho, \qquad (3)$$

where

$$A = \frac{\tau \bar{a} S v^5}{16Q}.$$

The intensity of the meteor's illumination, as formula (3) shows, is in a linear dependence on atmospheric density ρ. For our example, we can therefore write two equations:

$$I_1 = A\rho_1 \qquad (4)$$

and

$$I_2 = A\rho_2. \qquad (5)$$

After transferring from intensity to stellar magnitudes according to Pogson's formula, we obtain:

$$\frac{J_1}{J_2} = \frac{\rho_1}{\rho_2} = 2{,}5^{m_2 - m_1} \qquad (6)$$

or

$$\Delta m = m_2 - m_1 = 2{,}5 \cdot \lg \frac{\rho_1}{\rho_2}. \qquad (7)$$

The change in the stellar magnitude of the meteor amounts to:

$$\Delta m = 2{,}5 \cdot \lg \frac{8{,}6 \cdot 10^{-10}}{8{,}6 \cdot 10^{-8}} = -5^m{,}0.$$

Consequently, a sudden change in atmospheric density by two orders causes a change in the brightness of a meteor by 5 stellar magnitudes. The meteor can not only meet one whirling mass on its path, but it can also meet several. In this case we will have several flares, which is often observed in practice.

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